Evaluation of Malathion, Synergized Pyrethrum, and a Diatomaceous Earth as Protectants Against Insects in SORGHUM GRAIN...In Small Bins

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Preface

This report presents the results of tests with synergized pyrethrum, a diatomaceous earth, and malathion at two dosage rates, each applied to infested sorghum grain as a protectant against insect attack.

This is the last of four closely related studies concerning experiments with insecticides applied to stored grain in small bins.

The first report, "Evaluation of Malathion, Synergized Pyrethrum, and Diatomaceous Earth As Wheat Protectants in Small Bins," Marketing Research Report No. 726, August 1965, presents results of studies on wheat. The second report, "Evaluation of Malathion, Synergized Pyrethrum, and Diatomaceous Earth on Shelled Corn as Protectants Against Insects . . . in Small Bins", Marketing Research Report No. 768, October 1966, describes the results of studies on corn. The third report, "Evaluation of Four Inert Dusts on Wheat as Protectants Against Insects . . . in Small Bins", Marketing Research Report No. 780, 1967, compares two diatomaceous earths and two silica aerogels at several dosage levels with the standard malathion application.

Trade names are used in this publication solely to provide specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture and does not imply either a recommendation for its use or an endorsement over comparable products.

These studies were completed at the Manhattan, Kans., Mid-West Grain Insects Investigations laboratory, Market Quality Research Division, Agricultural Research Service, U. S. Department of Agriculture. J. L. Wilson, Ralph L. Ernst, Warren E. Blodgett, and Leon H. Hendricks, all of the Stored-Product Insects Research Branch, performed some of the entomological phases of the study. All residue determinations were made by the Chemical Unit at the Stored-Product Insects Research and Development Laboratory, Savannah, Ga.

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PRECAUTIONS

Pesticides used improperly can be injurious to man and animals. Use them only when needed and handle them with care. Follow the directions and heed all precautions on the labels.

Some States have special restrictions on the use of certain pesticides. Before applying pesticides, check State and local regulations.

Keep pesticides in closed, well-labeled containers in a dry place. Store them where they will not contaminate food or feed, and where children and animals cannot reach them. Promptly dispose of empty pesticide containers; do not use them for any other purpose.

Contents

Evaluation of Malathion, Synergized Pyrethrum, and a Diatomaceous Earth as Protectants Against Insects In Sorghum Grain . . . In Small Bins

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SUMMARY

Malathion at two dosage rates, synergized pyrethrum, and a diatomaceous earth were applied to sorghum grain to control an existing insect infestation and to prevent further insect damage. The treated grain was stored in 5-cubic-foot masonite bins for 12 months in a heated structure. Insect infestations were not adequately controlled by any of the treatments, as damaging populations became firmly established in all bins during the 12-month period.

The 1.5-pint dosage of malathion per 1,000 bushels gave the best protection. It killed nearly all rice weevils for 6 months after the sorghum was treated, and most of the confused flour beetles for the first 3 months. Treatment with the 1.0-pint dosage of malathion afforded some protection, but did not kill a majority of the rice weevils after 3 months, nor of the confused flour beetles after the first week. The reductions in insect mortality paralleled the reductions in malathion residues recovered from the grain. Rice weevils neither preferred nor avoided the malathion-treated sorghum grain in food selection studies.

Residues from the synergized pyrethrum treatment killed most of the rice weevils during the first week, but not after that, and did not kill many of the confused flour beetles at any time. Piperonyl butoxide residues degraded more or less gradually during the first 3 months to a stabilized level, which persisted until near the end of the storage period. Repellency of the synergized pyrethrum-treated grain was high initially but diminished as storage continued.

The diatomaceous earth treatment killed rice weevils for 1 month only and had no adverse effect on confused flour beetles in any of the tests. Repellency lessened with the increase in damage to the grain.

BACKGROUND AND OBJECTIVES

Sorghum grain in farm storage is usually infested by stored-grain insect pests soon after harvest, unless control measures are applied. The sorghum grain used in this study was stored on the farm for about 6 weeks, during which time it became infested by a variety of insects. Cool winter weather then prevented a great amount of damage during further temporary storage in a metal holding bin.

The primary objectives of this study were to compare the effectiveness of malathion and synergized pyrethrum emulsions and a diatomaceous earth in controlling the existing insect infestations and in preventing the establishment of other infestations during a continuous exposure to free-moving insect populations released in the storage area.

Other extensive intermediate-type storage studies with corn,[1] farmers stock peanuts,[2] and wheat,[3] have successfully used small 5-cubic-

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[1] LA HUE, D. W., WOMACK, HERBERT, and CLEMENTS, B. W., Jr. TREATMENTS FOR THE PROTECTION OF STORED SOUTHERN-GROWN CORN FROM RICE WEEVIL ATTACK—EXPLORATORY TESTS. U.S. Dept. Agr. Market. Res. Rpt. 272, 22 pp., illus. 1958.

[2] LA HUE, D. W., CLEMENTS, B. W., Jr., and WOMACK, HERBERT. IN-STORAGE TREATMENTS FOR THE PROTECTION OF FARMERS STOCK PEANUTS FROM INSECT DAMAGE—EXPLORATORY TESTS. U.S. Dept. Agr. Market. Res. Rpt. 363, 32 pp., illus. 1959.

[3] LA HUE, DELMON W. EVALUATION OF MALATHION, SYNERGIZED PYRETHRUM, AND DIATOMACEOUS EARTH AS WHEAT PROTECTANTS . . . IN SMALL BINS. U.S. Dept. Agr. Market. Res. Rpt. 726, 13 pp., illus. 1965.

foot cylindrical bins. Field-scale, large-bin, and warehouse tests are expensive and slow, they tie up storage facilities, and they can include only a restricted number of variables and replications. Laboratory tests in glass jars are limited in scope and are not representative of actual conditions in the field. The intermediate-type tests explore on a larger scale the dosage rates and residue degradation of materials found promising in the jar tests. Only the materials that continue to show promise are then tested with selected dosages in the field-scale, large-volume experiments.

MATERIALS AND METHODS

The treatments were applied during January 1961. Emulsion sprays prepared from premium-grade 57-percent malathion emulsifiable concentrate were applied to 20-bushel lots at the recommended dosage of 1.0 pint per 1,000 bushels and at 1.5 pints. A synergized pyrethrum emulsifiable concentrate (Pyrenone® 60–6 O. T.) was applied at the recommended rate of 1.0 quart per 1,000 bushels. Neutral distilled water was used in formulating the sprays for application by a Mist-O-Matic Seed Treater, adjusted to apply 5 gallons of finished spray per 1,000 bushels of grain. Extra spray was prepared to allow for proper agitation and application.

The diatomaceous earth (Perma-Guard®) was applied at the rate of 125 pounds per 1,000 bushels or about 4.17 pounds per ton. It was thoroughly mixed with the sorghum grain by rotating them in a steel barrel roller for 5 minutes.

Immediately after an individual treatment, about 4 bushels of the grain was poured into each of 5 bins, 5 cubic feet each, set on a 2-foot-square sheet of building felt over a masonite base. Five replicates of each treatment and 5 untreated check bins were placed in a randomized 5- by 5-block arrangement in a 14- by 16-foot upstairs room of a heated dwelling house.

Rice weevils (*Sitophilus oryzae* (L.)), confused flour beetles (*Tribolium confusum* Jacquelin duVal), red flour beetles (*T. castaneum* (Herbst)), flat grain beetles (*Cryptolestes pusillus* (Schönherr)), and saw-toothed grain beetles (*Oryzaephilus surinamensis* (L.)) were reared on wheat, corn, and sorghum grain and standard laboratory rearing nutriments. About 7,000 of these insects were scattered in the aisles and around the bins in the infestation room 14 days after the experiment was started. Additional releases of 6,400, 5,850, and 4,900 insects were made after 49, 117, and 210 days.

SAMPLING

Bulk lots of untreated sorghum grain were set aside from each treatment lot for later use in laboratory tests, and for comparison with treated grain in the infestation room. Replicated composite samples of each treatment variation were taken as the treated seed fell from the seed treater or was poured from the barrel roller. Later, after the grain had been divided into replicates and placed in the appropriate bins, other samples were taken from each bin as the surfaces were made uniformly level. These samples were left undisturbed in open 1-gallon, large-mouthed glass jars in the infestation room, continuously exposed to the mixed populations of insects moving about freely. These samples were used to estimate, by a visible assessment of damage, the effect of the initial handling procedures and of the subsequent molestation of the bins by periodic probings. Other composite samples were taken for the determinations of the moisture content, test weight, and chemical residues immediately after treatment.

Seven days after the storage test was begun, and 1, 3, 6, 9, and 12 months later, six samples of grain were taken from each bin with a nonpartitioned grain trier or probe. The probe was inserted twice near the center of each bin and once about 2 inches from the bin wall in each quadrant. Insects were immediately screened out of the probe samples and were counted for an estimate of the populations in the various bins. Dust from the samples from bins with the diatomaceous earth treatment was screened out and returned for thorough mixing with the parent sample.

Replicated 125-gram subsamples were taken from the probe samples and placed in ½-pint cardboard cartons to be used for the toxicity or bioassay tests. Later, other subsamples

were prepared for the food selection tests conducted 6 and 12 months after treatment. In these food preference or selection chambers, grain treated with the various materials is offered in separate cups around the edge of the chamber. Adult rice weevils, released in the center of the chamber, are allowed 24 hours to disperse and enter the grain that they prefer. The percentages that choose the different kinds of treated grain give a measure of the repellency or attraction of the different treatments to the insects.

After the bioassay and food selection tests had been completed and all free-crawling insects removed, the subsample replicates from the individual bins were combined and stored in screen-covered, 1-quart jars for estimates of the damage resulting from the development of progeny of the insects involved.

The remainder of the sorghum grain from the probe samples was kept in sealed, 1-gallon jars until used to determine the moisture content, weight per bushel, and insecticidal residues persisting at the various intervals of storage.

After each major introduction of insects to the infestation room, observations were made to determine whether or not the insects were entering the different treatments in about equal numbers. Other observations were made of the number of insects in the different areas of the infestation room. The amount of dust around the base of each bin was recorded as an indication of the insect activity and damage within the bin.

As the individual bins were emptied at the end of the test, two duplicate 1-gallon samples were progressively collected from top to bottom. After a screening to remove the insects, kernel bits, and frass, the samples were kept for 45 days to record the numbers of insects that emerged from the internal infestation existing at that time. The kernel bits and insects were screened out of the frass, which was then weighed to estimate the insect damage to the sorghum grain. Also, five replicated 100-kernel samples from each bin were examined to determine the percent of kernels damaged by insects and to calculate the loss in kernel weight due to insect feeding.

RESULTS

Moisture Content

The temperature in the infestation room ranged from 69° to 95° F. during the summer and from 52° to 87° during the winter. Humidity was not controlled. It ranged from 19 to 50 percent during the winter months at the beginning and end of the 1-year storage period, when the forced-air-circulating, gas-fired furnace was operating. The moisture content of the bin samples, as determined on a Steinlite 512 RC moisture tester, was reduced about 3.25 percentage points during the first 3 months of storage, reflecting this low humidity in the infestation room (table 1). During the last 3

TABLE 1.—*Moisture content of sorghum grain at various intervals after insecticide treatment*

Insecticide and dosage per 1,000 bushels	Moisture content after [1]—					
	7 days	1 month	3 months	6 months	9 months	12 months
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Malathion:						
1.0 pint	13.49	12.18	10.25	10.73	10.94	9.81
1.5 pints	13.51	12.44	10.21	10.81	10.99	9.54
Synergized pyrethrum:						
1.0 quart	13.57	12.04	10.20	10.92	11.24	10.23
Diatomaceous earth:						
125 pounds	13.05	11.72	10.12	11.01	11.00	10.41
Untreated check	13.41	12.25	10.25	11.17	11.23	10.69

[1] Moisture content averaged 13.43 percent before treatment.

months of storage, the moisture content decreased again slightly despite the relatively larger amount of insect activity in practically all of the bins. During the spring and summer, the humidity in the infestation room ranged from 27 to 94 percent, closely paralleling the outside atmospheric changes. Even with this higher humidity, there was little change in the moisture content of the grain during the summer.

Insecticide Residues

The recovery immediately after treatment of only 4.40 p.p.m. malathion from the 1.0-pint application was low (table 2); however, the results from the different bins were quite consistent. Within 3 months the residue had fallen to 1.30 p.p.m. An initial recovery of 11.02 p.p.m. malathion from the 1.5-pint application was reduced to less than 2.0 p.p.m. in 6 months of storage.

On grain treated with synergized pyrethrum, it has been assumed that recovery of piperonyl butoxide can be used to estimate the residues of pyrethrins at a 10 to 1 ratio. The initial recovery was 12.96 p.p.m. of piperonyl butoxide, which was quite uniform from bin to bin, and a gradual degradation pattern is evident.

Insect Populations

Large numbers of insects were uniformly distributed on the floor of the infestation room and on the walls adjacent to the bins throughout the storage period. The amount of insect excrement or frass around the bases of the bins indicated the insect activity within the bins.

All of the bins containing untreated sorghum grain and grain treated with the diatomaceous earth had traces or small amounts of dust around their bases after only 3 months' storage, and progressively larger amounts were recorded after that. Accumulations of dusts in progressively larger amounts were recorded around the bins of grain treated with the synergized pyrethrum after the fourth month of storage. The group of bins with the malathion applications consistently showed less dust than any of the other bins.

The numbers of live adult insects recovered from the probe samples from all bins at the specified sampling intervals (table 3) indicate the relative populations within the bins throughout the test period. After 3 months, 2,607 insects were found in all of the untreated check bins, and 1,156 in the bins of grain treated with diatomaceous earth. There were only 462 insects from grain with the synergized pyrethrum treatment and 398 and 144 insects, respectively, from the grain with 1.0- and 1.5-pint applications of malathion. Thereafter, the residues on the grain were not sufficient in any of the treatments to control the development of large populations, although the 1.5-

TABLE 2.—*Residues on sorghum grain at various intervals after insecticide treatment*

Insecticide and dosage per 1,000 bushels	Calculated application	Residues recovered by chemical analysis [1]—					
		Immediately after treatment	After 1 month	After 3 months	After 6 months	After 9 months	After 12 months
	P.p.m.	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*
Malathion: [2]							
1.0 pint	11.43	4.40	3.62	1.30	0.34	0.42	0.56
1.5 pints	17.14	11.02	6.00	3.62	1.44	1.42	1.14
Synergized pyrethrum: [3]							
1.0 quart	23.29	12.96	11.84	8.36	8.44	7.12	4.40

[1] Values are expressed in parts per million of the insecticide, based on actual weight of the sorghum grain.

[2] Premium-grade 57-percent malathion emulsifiable concentrate.

[3] Pyrenone® 60–6 O.T. Analyses were made for piperonyl butoxide. It is assumed that recoveries of piperonyl butoxide can be used to estimate the residues of pyrethrins at a 10 to 1 ratio.

TABLE 3.—*Live adult insects recovered from all probe samples of insecticide-treated sorghum grain during the 12-month test period*

Insecticide and dosage per 1,000 bushels	Insects in samples taken after—				
	1 month	3 months	6 months	9 months	12 months
	Number	*Number*	*Number*	*Number*	*Number*
Malathion:					
1.0 pint	28	398	4,264	2,857	2,057
1.5 pints	16	144	1,850	1,845	900
Synergized pyrethrum:					
1.0 quart	58	462	4,764	4,518	5,711
Diatomaceous earth:					
125 pounds	196	1,156	5,248	4,457	3,613
Untreated check	221	2,607	5,156	5,735	2,412

pint application of malathion somewhat suppressed the insects.

The numbers of insects, predominantly rice weevils, seen entering the sorghum grain in the various bins, during 30-minute counting periods 4 to 6 hours after major releases of insects in the infestation room, are recorded in table 4. About 30 percent of the total insects counted entered the untreated check bins, and another 30 percent entered each dosage group of bins in which the sorghum grain was treated with malathion. In direct contrast, only 2.82 and 5.74 percent of the insects were seen entering the bins treated with synergized pyrethrum and diatomaceous earth, respectively, during the initial counts 14 days after the test began. The repellency of the diatomaceous earth lessened considerably as the storage period lengthened. Neither the repellent action nor the residues remaining on the sorghum grain could prevent extensive damage to the sorghum grain treated with the synergized pyrethrum and the diatomaceous earth.

Food Selection Studies

Food preference test chambers were not available at the start of the test; therefore food selection studies were conducted only at the 6- and 12-month sampling periods. Cleaned grain that had been subjected to a temperature of —20° F. to kill all insects present was treated in the laboratory with the same materials used in the bin tests. Malathion definitely did not repel the weevils, but apparently

TABLE 4.—*Percentage of insects observed entering bins of sorghum grain during 30-minute observation periods following major insect releases made at various intervals after insecticide treatment*

Insecticide and dosage per 1,000 bushels	14 days	49 days	117 days	210 days
	Percent	*Percent*	*Percent*	*Percent*
Malathion:				
1.0 pint	30.97	29.07	26.08	24.20
1.5 pints	29.92	29.38	26.31	22.97
Synergized pyrethrum:				
1.0 quart	2.82	2.66	4.95	7.55
Diatomaceous earth:				
125 pounds	5.74	8.58	16.40	24.34
Untreated check	30.55	30.31	26.25	20.94

TABLE 5.—*Response of rice weevils to insecticide-treated sorghum grain in food selection studies*

Insecticide and dosage per 1,000 bushels	Percentage of weevils that entered samples after storage period of—				
	1 month [1]	6 months [1]	6 months [2]	12 months [1]	12 months [2]
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Malathion:					
1.0 pint	26.81	28.80	23.81	26.25	22.89
1.5 pints	28.09	24.17	21.76	27.03	21.94
Synergized pyrethrum:					
1.0 quart	9.12	11.36	19.85	13.13	15.94
Diatomaceous earth:					
125 pounds	8.76	13.30	17.22	13.42	17.85
Untreated check	27.21	22.37	17.35	20.16	21.37

[1] Laboratory-treated samples prepared with insect-damaged, cleaned sorghum grain containing 12.16, 11.07, and 10.73 percent moisture, respectively, for the 1-, 6-, and 12-month exposures.

[2] Samples from bins.

synergized pyrethrum and diatomaceous earth did, since fewer insects entered the cups of sorghum grain treated with them (table 5). Except in diatomaceous earth, synergized pyrethrum, and the untreated check, there was no significant change in repellency as storage time increased. The results of these tests show some correlation with the observations made of the number of insects entering the bins as shown in table 4.

Toxicity Studies

For the toxicity tests, about 50 rice weevils or 50 confused flour beetles were placed in each of ½-pint cardboard cartons containing 125-gram subsamples of the probe samples. The cartons were stored in the infestation room. Mortality was read at the end of 7 days and again at 14 days.

Both dosages of malathion killed all or nearly all of the rice weevils for 3 months, and the 1.5-pint dosage killed most of them 6 months after it had been applied (table 6). The effectiveness of the synergized pyrethrum was short lived—less than 50 percent of the rice weevils were killed after the treatment was 1 month old. The diatomaceous earth gave satisfactory kills of rice weevils for only 1 month, even though the moisture content was relatively low thereafter.

The 1.5-pint dosage of malathion gave fairly good initial kill of the confused flour beetles, but its effectiveness diminished rapidly and very little killing action was evident at 6 or 12 months (table 7). The kills of the confused flour beetle by the other treatments were completely unsatisfactory.

Insect Emergence

The 1-gallon samples from the bins at the termination of the study were screened of all dusts, kernel bits, and free-moving insects. All samples were infested, but relatively fewer live insects were noted in the screenings from samples with the malathion treatments.

The screened grain was held for an additional 45 days to record the emergence of insects from the internal infestations (table 8). Considerable numbers of insects emerged from the untreated sorghum grain and sorghum grain with the synergized pyrethrum and diatomaceous earth treatments.

The fewest insects emerged from the samples with the malathion treatments. Even though the 1.5-pint dosage was more effective in suppressing the populations, considerable kernel damage was evident.

Insect Damage

Assessments of the amount of damage to the sorghum grain were made by determining the percent of kernels damaged by insects, recording the amounts of insect frass, rating the

TABLE 6.—RICE WEEVIL ADULTS: *Mortality after exposures of 7 and 14 days to samples of insecticide-treated sorghum grain*

Exposure period, insecticide, and dosage per 1,000 bushels	Mortality of insects released in sorghum grain samples taken after a storage period of—					
	7 days	1 month	3 months	6 months	9 months	12 months
7 days:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Malathion:						
1.0 pint	100	100	79.8	31.1	[1]	[1]
1.5 pints	100	100	100	80.1	[1]	[1]
Synergized pyrethrum:						
1.0 quart	91.2	18.3	2.4	2.0	[1]	[1]
Diatomaceous earth:						
125 pounds	50.2	91.7	8.0	4.0	[1]	[1]
Untreated check	1.7	4.6	.5	3.5	[1]	[1]
14 days:						
Malathion:						
1.0 pint	[2]	[2]	98.7	42.6	10.7	36.0
1.5 pints	[2]	[2]	[2]	94.8	58.5	47.1
Synergized pyrethrum:						
1.0 quart	97.2	45.0	7.0	5.4	3.7	27.8
Diatomaceous earth:						
125 pounds	90.7	95.3	15.5	8.3	6.9	22.0
Untreated check	6.0	13.3	3.3	6.3	5.0	15.9

[1] Readings not made. [2] 100 percent mortality at 7-day reading.

TABLE 7.—CONFUSED FLOUR BEETLE ADULTS: *Mortality after exposures of 7 and 14 days to samples of insecticide-treated sorghum grain*

Exposure period, insecticide, and dosage per 1,000 bushels	Mortality of insects released in sorghum grain samples taken after a storage period of—				
	7 days	1 month	3 months	6 months	12 months
7 days:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Malathion:					
1.0 pint	33.1	25.5	2.4	1.9	[1]
1.5 pints	78.1	64.5	17.2	5.8	[1]
Synergized pyrethrum:					
1.0 quart	.4	3.0	.4	2.0	[1]
Diatomaceous earth:					
125 pounds	.4	.2	2.0	1.4	[1]
Untreated check	.5	.8	.2	2.2	[1]
14 days:					
Malathion:					
1.0 pint	68.9	35.5	25.8	2.9	5.4
1.5 pints	92.8	72.9	68.0	10.2	4.7
Synergized pyrethrum:					
1.0 quart	1.2	6.9	.9	2.2	2.4
Diatomaceous earth:					
125 pounds	2.0	3.8	3.3	3.1	2.7
Untreated check	.5	1.6	1.4	2.5	2.5

[1] Readings not made.

TABLE 8.—*Emergence of live adult insects from 1-gallon samples of insecticide-treated sorghum grain taken at the end of the tests and held for 45 days*

Insecticide and dosage per 1,000 bushels	Rice weevils	Flour beetles	Flat grain beetles	Others	Total
	Number	*Number*	*Number*	*Number*	*Number*
Malathion:					
1.0 pint	1,111	145	259	5	1,520
1.5 pints	903	27	73	4	1,007
Synergized pyrethrum:					
1.0 quart	2,259	468	3,996	16	6,739
Diatomaceous earth:					
125 pounds	4,204	413	2,434	43	7,094
Untreated check	3,439	349	2,285	72	6,145

visible damage to jar samples, recording losses in test weight, and calculating the kernel weight losses.

In all of the assessments, although the residue of malathion did not protect the sorghum grain completely, far less damage occurred in grain treated with either dosage of malathion than in grain with any of the other treatments.

The samples taken immediately after treatment showed less damage than those taken during the leveling of the surface of the binned grain (tables 9 and 10). In both lots, samples from the 1.5-pint application of malathion sustained the least damage. The 1.0-pint application was next best. In grain with the synergized pyrethrum and diatomaceous earth treatments, samples taken immediately after treatment were severely damaged after 7 months' storage but not as severely as samples of the same grain after it had been handled in filling and leveling the bins.

To determine the extent of infestation in the grain before the insecticides were applied, twenty-five 1-gallon samples of untreated grain were placed in individual jars. Infestations developed in 17 of them.

TABLE 9.—*Visible damage observed after various intervals in 1-gallon jar samples of sorghum grain collected immediately after insecticide treatment and subjected to mixed populations of insects*

Insecticide and dosage per 1,000 bushels	Insect damage observed after interval of [1]—					
	4 months	5 months	6 months	7 months	9 months	12 months
	Rating	*Rating*	*Rating*	*Rating*	*Rating*	*Rating*
Malathion:						
1.0 pint	0	0	0	0.6	1.0	1.8
1.5 pints	0	0	0	0	.4	1.0
Synergized pyrethrum:						
1.0 quart	1.0	1.0	2.6	3.6	5.0	.....
Diatomaceous earth:						
125 pounds	1.6	2.8	3.4	4.2	5.0	.....
Untreated check	1.6	2.8	4.0	5.0	.....	.....

[1] Damage rating code: 0=no visible infestation; 1=slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4=ascending numbers of insects and corresponding amount of insect frass; 5=large infestation with great amounts of insect frass and spoilage of grain.

TABLE 10.—*Visible damage observed after various intervals in 1-gallon jar samples of insecticide-treated sorghum grain collected during binning procedures and subjected to mixed populations of insects*

Insecticide and dosage per 1,000 bushels	Insect damage observed after interval of [1]—					
	4 months	5 months	6 months	7 months	9 months	12 months
	Rating	*Rating*	*Rating*	*Rating*	*Rating*	*Rating*
Malathion:						
1.0 pint	0	0	0.6	1.4	1.6	2.4
1.5 pints	0	0	0	.6	1.0	1.8
Synergized pyrethrum:						
1.0 quart	2.2	2.8	3.4	4.0	5.0	.....
Diatomaceous earth:						
125 pounds	3.2	4.4	5.0	.....	.....	.....
Untreated check	3.0	4.2	5.0	.....	.....	.....

[1] Damage rating code: 0=no visible infestation; 1=slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4=ascending numbers of insects and corresponding amount of insect frass; 5=large infestation with great amounts of insect frass and spoilage of grain.

The weights of insect frass and other fine dusts sifted from the 1-gallon samples collected as the bins were emptied during the termination of the study indicated the amount of insect activity and damage to the kernels during the 12-month storage period. Although the smallest amount of dust was recovered from the 1.5-pint dosage of malathion (table 11), considerable damage to the kernels had been done. Nearly as much frass and other fine dusts were recovered from the synergized pyrethrum and the diatomaceous earth treatments as from the untreated material. The separation of the insect frass and fine grain dusts from the very small amount of the diatomaceous earth falling free from grain with that treatment was not feasible.

TABLE 11.—*Weight of insect frass from 1-gallon samples of insecticide-treated sorghum grain*

Insecticide and dosage per 1,000 bushels	Average	Range
	Grams	*Grams*
Malathion:		
1.0 pint	55.4	46.2–65.4
1.5 pints	32.1	23.8–40.5
Synergized pyrethrum:		
1.0 quart	142.0	101.9–187.6
Diatomaceous earth:		
125 pounds	165.0	142.4–190.1
Untreated check	173.9	134.5–234.3

Damage in terms of weight loss caused by insect feeding has a direct bearing on evaluation of the effectiveness of a protectant. The changes in the test weight per bushel of grain for the different treatments by sampling periods are shown in table 12. The test weights for all treatments declined with the length of the storage period. The least damage occurred in the grain treated with the 1.5-pint application of malathion, and the 1-pint malathion treatment was next most effective. Losses in test weight of about 8 pounds per bushel were recorded in the sorghum grain from the synergized pyrethrum and diatomaceous earth treatments and in the untreated check grain.

Samples of 500 kernels from each bin were examined at the end of the test to determine the percentage of kernels damaged by insects and to calculate kernel weight loss due to feeding of the insects. Heavily damaged kernels, especially those with extensive internal feeding, are often broken up during the screening process and, consequently, are not recorded by this

TABLE 12.—*Test weights of insecticide-treated sorghum grain at given intervals during the storage period*

Insecticide and dosage per 1,000 bushels	Weight per bushel					Loss during storage
	Immediately after treatment	After 3 months	After 6 months	After 9 months	After 12 months	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Malathion:						
1.0 pint	58.0	57.3	57.6	55.8	54.3	3.7
1.5 pints	58.0	58.2	58.1	56.7	56.1	1.9
Synergized pyrethrum:						
1.0 quart	58.0	57.1	56.8	53.2	50.2	7.8
Diatomaceous earth:						
125 pounds	56.6	55.4	54.6	52.4	48.0	8.6
Untreated check	58.0	55.6	54.5	52.8	50.4	7.6

method of testing kernel damage. The percent of kernels damaged ranged from 37.16 and 59.92 percent in the 1.5-pint and 1.0-pint applications of malathion to 76.56 and 80.64 in the synergized pyrethrum and diatomaceous earth treatments in comparison with the more than 90 percent kernel damage that occurred in the untreated check (table 13). Calculated kernel weight losses ranged from 13.36 and 19.29 percent in the 1.5- and 1.0-pint dosages of malathion to 26.36 and 28.48 percent with the synergized pyrethrum and diatomaceous earth treatments.

TABLE 13.—*Kernel damage and calculated weight loss in insecticide-treated sorghum grain after the 12-month test period*

Insecticide and dosage per 1,000 bushels	Kernels damaged [1]	Weight loss
	Percent	*Percent*
Malathion:		
1.0 pint	59.92	19.29
1.5 pints	37.16	13.36
Synergized pyrethrum:		
1.0 quart	76.56	26.36
Diatomaceous earth:		
125 pounds	80.64	28.48
Untreated check	90.28	31.31

[1] An average of 5.3 percent of the kernels were damaged before treatment.

Progeny Damage

Data obtained on progeny damage to composite samples of the subsamples that had been exposed to insects in toxicity and food selection studies substantiated other findings and results. Table 14 shows that residues from both malathion treatments were effective during the 1- and 3-month storage periods. This effectiveness rapidly diminished thereafter, although some protection was given, as shown by a comparison of the readings from these treatments with those from the synergized pyrethrum and diatomaceous earth treatments.

FINDINGS

An evaluation was made in small-bin laboratory tests of the protectant properties of two dosages of malathion, and of single dosages of synergized pyrethrum and a diatomaceous earth when applied to insect-infested, uncleaned sorghum grain. The following conclusions were drawn:

(1) None of the insecticides prevented insect damage to the sorghum grain for the whole 12-month storage period.

(2) Although not giving adequate protection, malathion applied at the rate of 1.5 pints per 1,000 bushels was more effective than any of the other treatments.

(3) Malathion residues degraded rapidly and, as determined by insect infestations in

TABLE 14.—*Visible damage by insect progeny observed in 1-quart samples of insecticide-treated sorghum grain composited from the toxicity test subsamples*

Insecticide and dosage per 1,000 bushels	Damage observed 6 months after a storage period of [1]—				
	1 month	3 months	6 months	9 months	12 months
	Rating	*Rating*	*Rating*	*Rating*	*Rating*
Malathion:					
1.0 pint	0.6	0.6	4.2	4.4	2.4
1.5 pints	0	0	2.4	2.6	1.4
Synergized pyrethrum:					
1.0 quart	3.0	3.2	4.8	5.0	4.6
Diatomaceous earth:					
125 pounds	3.0	4.8	5.0	5.0	5.0
Untreated check	3.6	4.2	5.0	5.0	5.0

[1] Damage rating code: 0=no visible infestation; 1=slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4=ascending numbers of insects and corresponding amounts of insect frass; 5=large infestation with great amounts of insect frass and spoilage of grain.

the bins, became ineffective in 3 to 6 months. The residues at these times were about 1.5 p.p.m. Ineffectiveness of malathion residues of less than 1.5 p.p.m. was also indicated in toxicity tests with rice weevils.

(4) The synergized pyrethrum gave satisfactory protection in the bins for 1 month and in the toxicity tests against the rice weevil only at the 7-day test period.

(5) The diatomaceous earth applied at the rate of 125 pounds per 1,000 bushels gave satisfactory control in the bins and in toxicity tests against rice weevils for only 1 month.

(6) The 1.5-pint dosage of malathion alone gave satisfactory kills of the confused flour beetle in the initial toxicity tests.

(7) The synergized pyrethrum and diatomaceous earth treatments rendered the sorghum grain about equally repellent to rice weevils in food selection tests, but the repellency was greatly reduced as the grain became more heavily infested and damaged with longer storage.

(8) Malathion was neither distinctly repellent nor attractive to the insects at either dosage rate.

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